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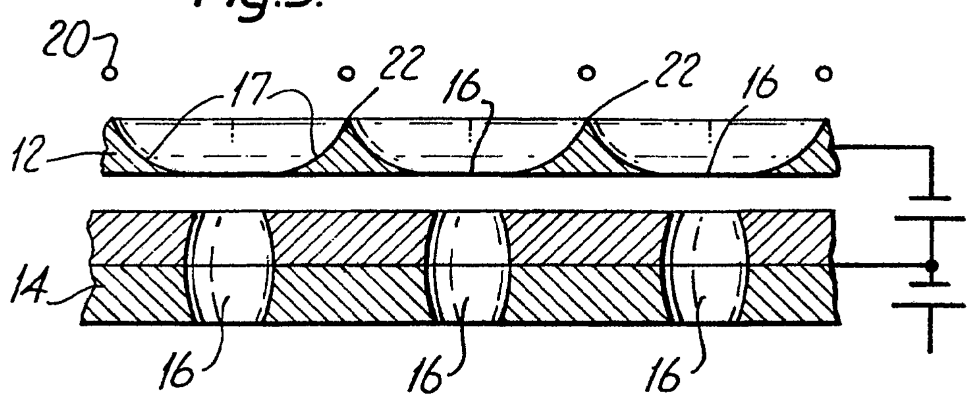
(54) A channel plate electron multiplier structure having a large input multiplying area

(57) A channel plate electron multiplier structure suitable for use in a photomultiplier tube comprises a plurality of discrete, apertured dynodes arranged as a stack with the apertures (16) in each dynode aligned with apertures in an adjacent dynode to provide channels. The apertures in the input dynode (12) diverge in the direction of incoming electrons to an extent that substantially the entire surface area of the input side constitutes the multiplying area.

By enlarging the multiplying area of the input dynode then the majority of the electrons produced by the photocathode (30) of a photomultiplier tube (24) can be captured irrespective of their angle of incidence. If desired a grid (20) may be arranged adjacent to, but spaced from, the input dynode (12). The grid (20) in use is held at a negative voltage relative to the input dynode (12) to provide a field which directs electrons from the multiplying area towards the apertures therein.

Fig.3.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig.1.

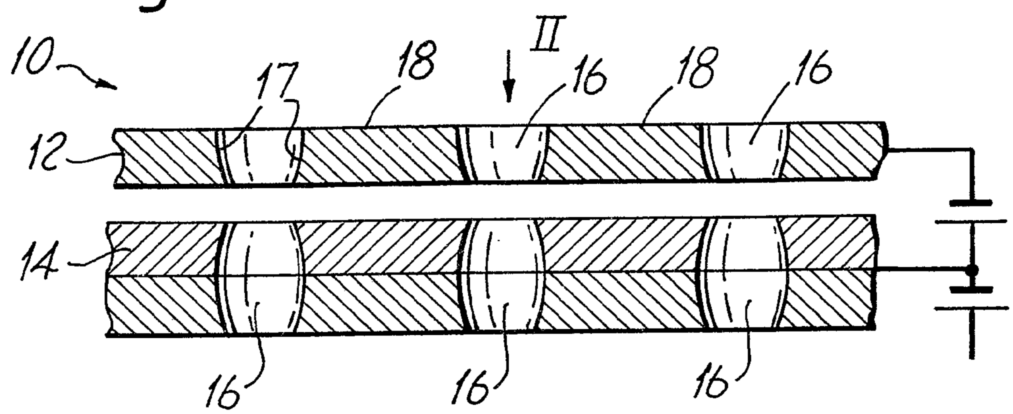


Fig.2.

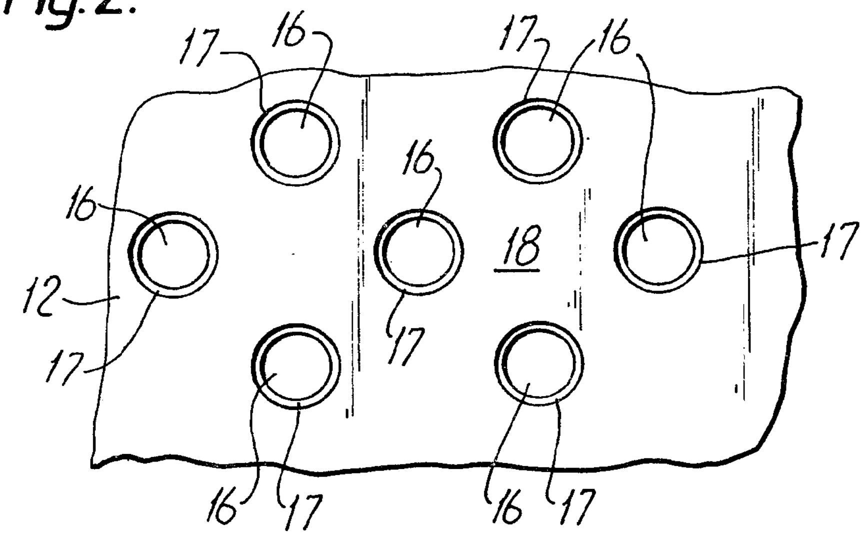


Fig.3.

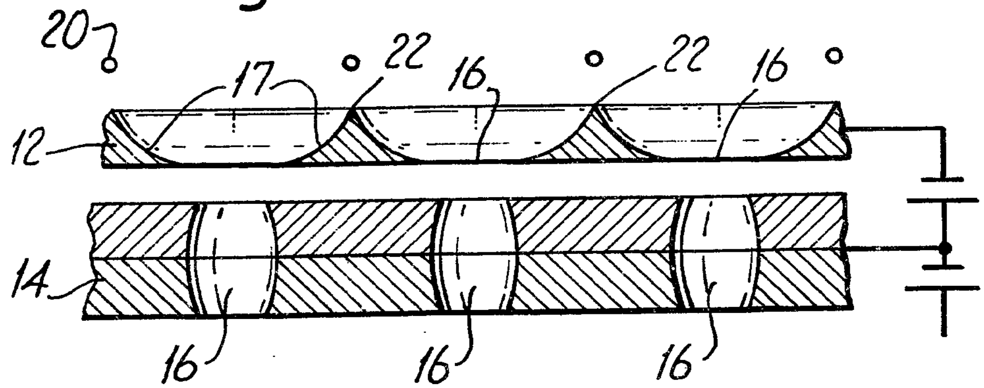


Fig.4.

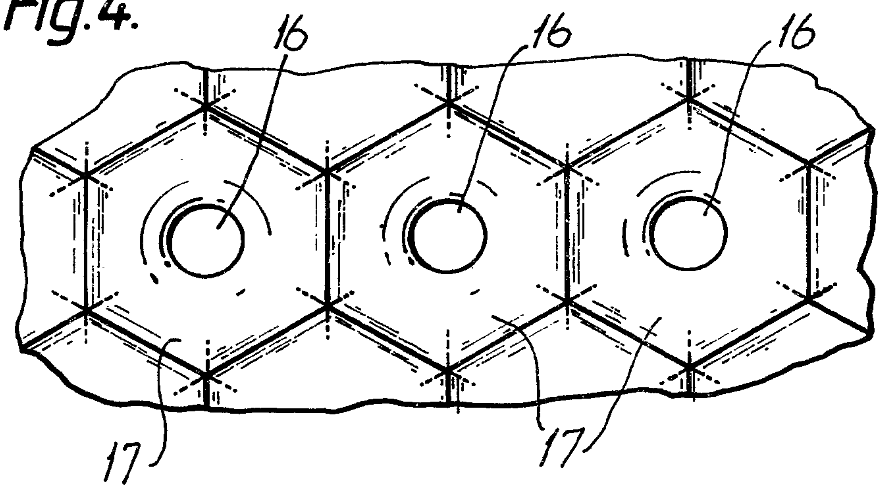
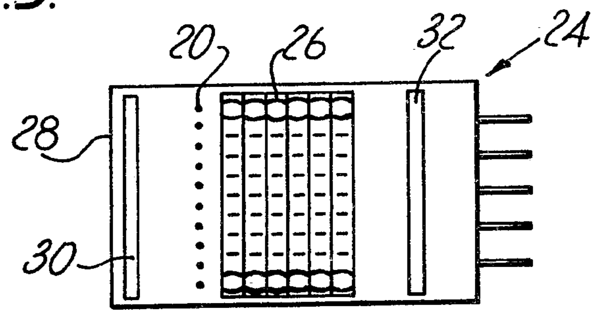


Fig.5.



SPECIFICATION

Channel plate electron multipliers

The present invention relates to channel plate electron multipliers having particular, but not exclusive, application in photomultiplier tubes.

Electron multipliers have been proposed for image display tubes, for example a laminated channel plate structure of the type disclosed in British Patent Specification 1,434,053 (PHB 32324), and for image intensifier tubes. In the case of image display tubes a low energy electron beam produced for example by an electron gun is scanned across the input side of a large area channel plate electron multiplier which is disposed at a short distance from a phosphor screen provided on the inner surface of a substantially parallel arranged faceplate. The electron beam undergoes amplification by current multiplication in the electron multiplier before being incident on the phosphor screen. In order to ensure uniform overall gain by each channel of the thousands of channels of the electron multiplier it is necessary to try and ensure that not only do all the channels have the same gain but also the electron beam being scanned across the input face of the electron multiplier is as uniform in cross-section as is possible so that under constant signal conditions substantially the same number of electrons enter each channel to provide an image of uniform intensity across the entire area of the faceplate. In the case of a display tube beam shaping can be provided by the electron gun and/or by the deflection means which may be electromagnetic or electrostatic.

In the case of an image intensifier tube, an expensive to produce, monolithic microchannel channel plate is now frequently used to provide a high gain image amplification. Here again the overall uniformity of amplification is dependent upon not only the characteristics of each channel of the microchannel plate electron multiplier but also on ensuring that under uniform lighting conditions substantially the same number of electrons enter each channel. As with the electron multiplier for an image display tube one is primarily interested in spatial information, that is the reproduction of an image, rather than determining that a particular event happened at a particular instant in time.

As is known photomultiplier tubes provide a high overall gain by electron multiplication. However, in use as scintillation detectors the photons from a scintillation or event can be incident on a photocathode at any one of a wide range of angles. Consequently, in order to amplify randomly occurring electrons properly it is essential to try and capture every photoelectron produced by the cathode. The channel plate electron multipliers used heretofore have been considered unsuitable for use in photomultiplier tubes because in the case of a microchannel plate it is too expensive and in the case of a laminated metal channel plate structure in order to record an event an incident photoelectron has to approach an aperture in an input dynode over a relatively small range of angles to enter a channel and be amplified otherwise it will strike the metal around each aperture and the event will effectively be lost. If the cross-sectional area of each channel is enlarged then this will lead to the overall structure being less rigid and therefore subject to the effects of vibration or alternatively if the number of channels is reduced this will lead to a reduced image definition.

Accordingly it is an object of the present invention to increase the detection efficiency of a channel plate electron multiplier.

According to the present invention there is provided a channel plate structure comprising a plurality of discrete apertured dynodes arranged as a stack with the apertures in each dynode aligned with apertures in an adjacent dynode to provide channels, the apertures in the input dynode diverging in the direction of incoming electrons, wherein the cross-sectional area of the apertures at the input surface of the input dynode is substantially greater than the maximum cross-sectional area of the apertures in successive dynodes.

If desired the apertures in the input dynode may diverge to an extent that substantially a major portion of the surface area constitutes an electron multiplying area, this may be achieved by arranging the apertures to diverge to such an extent that the peripheries of adjoining apertures meet.

The present invention also provides a photomultiplier tube comprising an envelope in which is provided a photocathode and a channel plate structure made in accordance with the present invention, the input dynode being disposed to receive electrons from the photocathode.

In an embodiment of a photomultiplier tube a grid is disposed adjacent to, but spaced from, the input dynode. In use the grid is held at a potential which is a few volts, say 10 volts, negative with respect to the input dynode in order to produce a field to direct secondary electrons from the first dynode towards the apertures therein. As a result more secondary electrons are used thereby providing a higher overall gain and an increase in detection of events. This latter advantage is of importance because if all the secondary electrons associated with an event escape then, from the point of view of recording, the event would not have taken.

According to another aspect of the present invention there is provided a method of making an input dynode for the channel plate structure in accordance with the present invention, comprising taking a metal sheet of greater thickness than the overall thickness of the finished input dynode, etching a plurality of apertures in the metal sheet, the apertures diverging in a direction from one surface of the other surface of the sheet, and etching the entire other surface of the sheet until its overall thickness corresponds to substantially the finished thickness of the dynode.

The present invention will now be explained and described, by way of example, with reference to the accompanying drawings, wherein

Figure 1 is a diagrammatic cross-sectional view of part of the first and second dynodes of a known channel plate electron multiplier,

Figure 2 is a plan view in the direction II in Figure 1,

Figure 3 is a diagrammatic cross-sectional view of part of the first and second dynodes of a channel plate electron multiplier made in accordance with the present invention together with a grid arranged adjacent to, but spaced from, the input side of the first dynode,

Figure 4 is a plan view of the first dynode in the direction III in Figure 3, and

Figure 5 is a diagrammatic longitudinal sectional view of a photomultiplier tube including the channel plate electron multiplier made in accordance with the present invention.

The known channel plate multiplier shown in Figures 1 and 2 is of a type disclosed fully in British Patent Specification 1,434,053 (PHB 32324) details of which are incorporated herein by way of reference. Insofar as the understanding of the present invention is concerned it is sufficient to point out that the channel plate electron multiplier 10 comprises a stack of apertured dynodes, say ten dynodes, of which the first two 12 and 14 are shown. The dynodes are insulated from each other. In use a different voltage is applied to each dynode so that the output dynode (not shown) is at a high positive voltage relative to the input or first dynode 12.

The apertures 16 in the dynodes are aligned to form the channels. Apart from the first dynode 12, the apertures 16 are of barrel shape when viewed in longitudinal cross-section. Conveniently apertures of such a shape are formed by etching a plurality of cup-shaped or divergent apertures in sheets of metal and then placing the sheets together so that the surfaces having apertures of the largest cross-section therein are placed face to face. However in the case of the input or first dynode 12, this comprises a single sheet arranged with its apertures diverging towards the direction of incoming electrons.

The metal sheets forming the dynodes may comprise mild steel of which the inside of the apertures 16 is provided with a coating of a secondary emissive material or a material such as a silver-magnesium alloy or a copper-beryllium alloy which is subsequently activated to produce a secondary emitting surface.

This know channel plate electron multiplier structure 10 is satisfactory for use in display tubes in which an electron beam of a predetermined cross-section shape is scanned in raster-like fashion across the input or first dynode 12. The divergent apertures 16 of the dynode 12 are adequate to capture the incident and secondary electrons and to direct them into the channels formed by the apertures to the second dynode. However as is evident from Figure 2 there is a large, relatively flat area 18 of the first dynode surface between the apertures 16 which area is less productive than a multiplying surface 17 within the apertures 16. In operation secondary electrons are created by the incoming electrons impinging on the multiplying surface 17 as well as on the flat area 18 between the apertures. Generally a majority of the secondary electrons produced from the multiplying surfaces 17 enter the apertures 16 proper but a large proportion of the secondary electrons produced from the flat area 18, which may be treated to reduce its coefficient of secondary emission, do not enter the channels formed by the aligned apertures 16 and so represent lost information. This loss of secondary electrons from the flat area 18 is not of great importance for display tube applications.

However the situation is different if the channnel plate electron multiplier is to be used in a photomultiplier tube because it is important to be able to detect as many incoming events as possible. This is achieved by the channel plate electron multiplier shown in Figures 3 and 4. For convenience of description corresponding reference numerals have been used to identify the same parts as in Figures 1 and 2.

Apart from the input or first dynode 12, the remainder of the stack of dynodes is as described with reference to Figures 1 and 2 and in the interests of brevity will not be described again.

The arrangement of the apertures 16 is such as to suit their intended purpose. However, their angle of divergence towards the direction of the incoming electrons is substantially greater such that the cross-section of each aperture at the input surface of the first dynode 12 is substantially greater than the maximum cross-sectional area of the barrel-shaped apertures in the second and subsequent dynodes. In order to obtain the maximum multiplying surface 17 each aperture 16 diverges to an extent that the peripheries of the multiplying surfaces 17 of adjoining apertures 16 meet so that a major portion of the plan area of the input surface constitutes the multiplying surface. Tests have shown that secondary electrons are generated on approximately 85% of the plan area of the first dynode shown in Figures 3 and 4 compared with approximately 24% in the case of the first dynode shown in Figures 1 and 2.

The first dynode 12 which has an overall finished thickness of, for example, 150 μm which is half that of the second and subsequent dynodes, can be made by taking a sheet of metal say a silver-magnesium alloy of a thickness of 400 μm. Cup-shaped apertures are etched through the metal in a known way, for example applying a photoresist, exposing the resist to light through an appropriate mask, washing away the unexposed resist and etching the material exposed. The resist is removed on the "large-hole" side which is then exposed to an etchant over the whole surface until its overall thickness is reduced to 150 μm. As can be seen from Figure 4 the meeting boundaries of the divergent apertures form a hexagonal pattern.

The detection efficiency of the first dynode can be increased by mounting a grid 20 adjacent to,

but spaced from, the input side of the first dynode 12. The mesh of the grid 20 is selected so as not to block the apertures 16 and conveniently its pitch coincides with points 22 where the peripheries of the multiplying surfaces 17 of the apertures 16 meet. In operation the grid 20 is say 10 volts negative with respect to the first dynode 12 and the field produced has the effect of turning the secondary electrons as they leave the multiplying surface such that they can enter the channels to be amplified. In a photomultiplier tube one is not interested in spatial information (as in an image tube) so that it does not matter if secondary electrons enter channels which are some distance from the multiplying surface from which they were produced.

Figure 5 illustrates diagrammatically a photomultiplier tube 24 incorporating a channel plate electron multiplier 26 made in accordance with the present invention. The tube 24 comprises a glass envelope 28 in which is provided a photocathode 30, the multiplier 26 having the grid 20 adjacent to, but spaced from, the input side of the multiplier 26 and an anode 32 by which an output signal is derived. In operation light, generally in the form of random impulses, impinges on the photocathode 30 from which electrons are derived. The electrons accelerate towards the multiplier 26, the input dynode being typically +300 volts with respect to the photocathode 30 and the grid 20 being at +290 volts with respect to the photocathode 30. The electrons undergo current multiplication and the output electron streams from the multiplier 26 are incident on the anode 32 to produce an output signal.

The channel plate electron multiplier shown in Figures 3 and 4 has been described in the context of being used in a photomultiplier tube, however it can also be used in other applications in which one is interested in detecting a high proportion of incoming electrons to produce an integrated output signal rather than producing an amplified version of an incoming signal in a situation where spatial correctness is of greater importance than total output.

CLAIMS

1. A channel plate structure comprising a plurality of discrete apertured dynodes arranged as a stack with the apertures in each dynode aligned with apertures in an adjacent dynode to provide channels, the apertures in the input dynode diverging in the direction of incoming electrons, wherein the cross-sectional area of the apertures at the input surface of the input dynode is substantially greater than the maximum cross-sectional area of the apertures in successive dynodes.

2. A structure as claimed in Claim 1, wherein the apertures in the input dynode diverge to an extent that substantially a major portion of surface area constitutes an electron multiplying area.

3. A structure as claimed in Claim 1 or 2, wherein the apertures in the input dynode diverge to an extent that the peripheries of adjoining apertures meet.

4. A channel plate structure substantially as hereinbefore described with reference to Figures 3 and 4 of the accompanying drawings.

5. A photomultiplier tube comprising an envelope in which is provided a photocathode and a channel plate structure as claimed in any one of Claims 1 to 4, the input dynode being disposed to receive electrons from the photocathode.

7. A photomultiplier tube substantially as hereinbefore described with reference to Figures 3 to 5 of the accompanying drawings.

8. A method of making an input dynode for the channel plate structure as claimed in any one of Claims 1 to 4, comprising taking a metal sheet of greater thickness than the overall thickness of the finished input dynode, etching a plurality of apertures in the metal sheet, the apertures diverging in a direction from one surface of the other surface of the sheet, and etching the entire other surface of the sheet until its overall thickness corresponds to substantially the finished thickness of the dynode.

9. A method of making an input dynode for the channel plate structure as claimed in any one of Claims 1 to 4, substantially as hereinbefore described.

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